SHORT NOTE

USE OF MICROPOROUS PLASTIC FOR IN-PACKAGE CONTROLLED ATMOSPHERES

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ABSTRACT

Ground beef packaged and stored with carbon dioxide-generating reagent packets made from (1) microporous plastic film or (2) non-woven cellulose cloth had significantly ($p<0.01$) lower bacterial counts than ground meat packaged and stored without packets. There was no significant difference ($p>0.05$) in bacterial counts of samples stored with the 2 types of packets. Samples with in-package generated carbon dioxide atmospheres had approximately 2-3 days additional shelf-life before spoilage.

INTRODUCTION

Increased levels of carbon dioxide (>5%) inhibit the growth of the psychrophilic, aerobic meat spoilage pseudomonads, possibly through inhibition of microbial decarboxylase systems (Enfors *et al.* 1979; Gill and Tan 1979). Solid carbon dioxide is commonly added to bulk containers of primal and subprimal cuts pre-transport to reduce microbial growth on meat surfaces during the period from packing plant to final market, but such inhibitory atmospheres are lost when the containers are opened. When the meat cuts are fabricated into the desired final form, e.g., roasts and steaks, and are packaged, the meat surfaces are exposed to the lower atmospheric concentrations of carbon dioxide. Polyvinyl chloride (PVC) stretch film, the commonly used meat wrap, is impermeable to water vapor but is permeable to oxygen and carbon dioxide at

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differential rates such that oxygen enters, maintaining the desired red meat color, and the protective carbon dioxide diffuses out. An in-package carbon dioxide generating system utilizing dry chemicals in packets was therefore developed in this laboratory to provide inhibitory levels of carbon dioxide during market storage and display after being wrapped (Benedict *et al.* 1975b). When moisture levels and the favorable conditions for microbial growth increase within the package, these selected dry chemical packets respond by gas release to counteract such growth. As water is a product along with the evolution of carbon dioxide from carbonic acid, the relative humidity levels within the package remain at levels necessary to prevent meat surface dehydration. By this technique the potential shelf life and quality of fresh carefully handled meat was extended.

In our experiments we prepared the packets for the dry chemicals by hand from nonwoven disposable cellulose fiber cloths into individual 1.5 in. by 3 in. envelopes sealed at edges with pressure sensitive tape. This material allowed free transport of water vapor into the envelope for the chemical reaction between the acid and salt of a volatile acid and permitted the formed gases to diffuse out into the package. Subsequent to publication of the above procedure, a microporous polypropylene film (MPF) was developed and became available commercially in 1975 ("Celgard", TM -Celanese Fibers[3]) (Bierenbaum *et al.* 1974). This allowed free transfer of gases, including water vapor, through the .02 to .04 μm pores but prevented transfer of liquid water. Since this material appeared to offer advantages in ease of fabrication, sanitation, and convenience, it was tested for effectiveness as a packaging material for the dry reagents in controlling microbial growth within the meat package.

MATERIALS AND METHODS

Beef semitendinosus muscle, 1 day postmortem, was excised and trimmed under aseptic conditions to give fresh tissue surfaces. The meat was aseptically ground 2X through a 1/4 in. plate in a sterilized grinder at 15° C, divided into 50 g samples for packaging, and placed on a sterile 12 cm × 12 cm × 2 cm plastic weigh tray. Packets made by hand from either the nonwoven cellulose cloth or microporous polypropylene film were filled with 5 g of citric acid-sodium bicarbonate mixture (Benedict *et al.* 1975b). Celgard 2400, of 38% porosity and 1 mil thickness, was used as the microporous plastic film. Each sample was divided randomly

[3] Reference to brand or firm name does not constitute endorsement by the U.S. Department of Agriculture over others of a similar nature not mentioned.

into the 3 experimental groups: I-no packet; II-cellulose fiber packet added; III-microporous polypropylene packet added, and overwrapped with PVC stretch film (FMC-MC). Total volume of wrapped sample was approximately 280 cc, including the ground meat sample volume of 50-60 cc and the chemical packet volume of 25-30 cc. Samples were analyzed following storage at -1.1°C at 1, 2, 3, 4, 7, 9, 11, 14, 15, 16, 17, 18, 20, and 21 days for aerobic bacterial counts, in triplicate, by the previously described method (Benedict *et al.* 1975b) except that samples were blended at top speed for 1 min in a Waring blendor instead of shaken. Results were reported as $\log_{10}$ counts/g meat. Statistical evaluation of the data was conducted by the paired "t" test according to Steel and Torrie (1960).

RESULTS AND DISCUSSION

Ground beef was selected for these experiments because grinding produces a greater surface area for aerobic microbial growth. Aerobic plate counts during the first 6 days of analysis were at or below a $\log_{10}$ value of 2.0/g beef for all 3 experimental groups. Counts represented micro-colonies of unidentified genera. Psychrotrophic catalase positive-gram negative bacillae (Pseudomonas-like) with an increased rate of growth replaced these micro-colonies after day 6. Complete reaction of the approximately 1.5 g sodium bicarbonate contained in the 5 g of the 4.5:2 mixture of citric acid-sodium bicarbonate would evolve over 400 ml carbon dioxide which by controlled release would be sufficient to produce a desired 15% carbon dioxide level in the ca 200 ml package atmosphere for over 13 days. In these experiments the release of carbon dioxide was not controlled. Reaction occurred after 2 to 4 days of storage at -1.1°C when moisture levels within the package reached levels necessary for reaction, and evolution of gas continued until day 8-9, with the peak at days 4-7. Although it is probable that continued control of carbon dioxide levels within the package could be maintained by various systems and so inhibit pseudomonad-like organism growth, a less detectable spoilage might then occur from growth of carbon dioxide tolerant lactic acid bacteria within the package. Log_{10} values for the average of triplicate determinations of the aerobic plate counts after various storage times for the three packaging variables are presented in Table 1. A value of 10^6 /g, taken as indication of incipient spoilage, would occur after 12.8 days with Treatment I, 15.5 days with Treatment II, and 14.5 days with Treatment III. Values of 10^7 /g which would be visible spoilage occurred 2 to 3 days later in each case. Statistical evaluation by the

Table 1. Aerobic plate counts for ground beef samples stored at -1.1°C for various time periods in PVC stretch film containing no carbon dioxide generating system (I), a cellulose fiber packet carbon dioxide generating system (II), or a microporous polypropylene packet carbon dioxide generating system (III)

Day of Storage	Aerobic Plate Count (Log_{10} CFU[a]/gm)		
	I	II	III
9[b]	3.52	2.40	2.48
11	3.63	2.00	2.85
14	7.10	4.00	4.00
15	7.95	5.10	6.40
16	8.69	6.46	6.60
17	8.95	6.20	6.28
18[c]	8.95	6.68	9.05

[a]CFU = colony forming units
[b]Values for all treatments were below 2.50 up to day 9
[c]Values for all treatments were above 8.0 after day 20

paired "t" test (Steel and Torrie 1960) indicated a "t" value of 4.59 (**) between I-II, 3.94 (**) between I-III, and 1.58 (N.S.) between II-III, where (**) indicates $p<0.01$, and N.S. indicates $p>0.05$. The grinding of the meat at 15° C under the conditions necessary for microbial sterility produced an increased oxidation of meat lipids and myoglobin that resulted in elevated thiobarbituric acid test values and in decreased red color for all samples after 4 days storage. With intact meat samples, surface color deterioration occurred at a much slower rate (Benedict *et al.* 1975a).

Although the 2 materials used to fabricate the packet do not differ significantly in their action, a microporous polypropylene film (MPF) for the dry chemical packets provides several potential advantages over the cellulose cloth. Such MPF packets may be fabricated and filled mechanically in volume. Since MPF can also be fabricated to most specifications of the user, the rate of gas production and release can be controlled more critically through selection of effective pore size, porosity, and hydrophobicity relative to reaction chemical content. With foodstuffs overwrapped in PVC or certain other stretch films, however, the differential loss of gases through the overwrap films must be considered in these calculations as gas transfer does not follow simple diffusion kinetics (Benedict *et al.* 1975b). Selection of the particular MPF packet material should be based on the type of overwrap film, nature of the product, and

volume of the package. Another advantage over cellulose fiber packets is that within visible food containers such as for wrapped meat or fruit, plastic packets present a more sanitary appearance and are less susceptible to staining by meat juices.

Although the dry chemical packets were designed for use with meat products and production of bacteriostatic levels of carbon dioxide, they might also be utilized for other commodities such as apples or grapes. Other reactants, e.g., acetic, propionic, sulfurous, and hydrochlorous acid salts, may be used where low in-package levels of these gases are desired to reduce fungal growth or for sanitation purposes.

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